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Recent Results and Future Plans for a 45 Actuator Adaptive X-ray Optics Experiment at the Advanced Light Source

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July 20, 2015

Synchrotron Radiation Instrumentation 2015
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Recent results and Future Plans for a 45 Actuator Adaptive X-ray Optics Experiment at the Advanced Light Source

Synchrotron Radiation Instrumentation - Focusing & Imaging Optics

July 8, 2015

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Lawrence Livermore National Laboratory

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LLNL-PRES-674140

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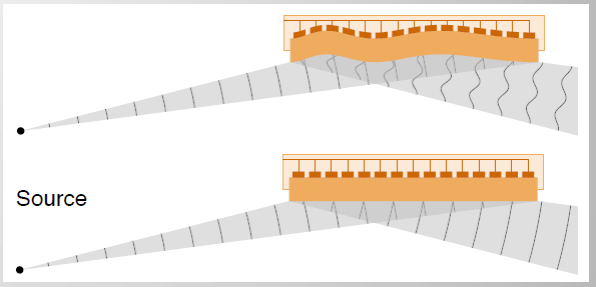
Overview

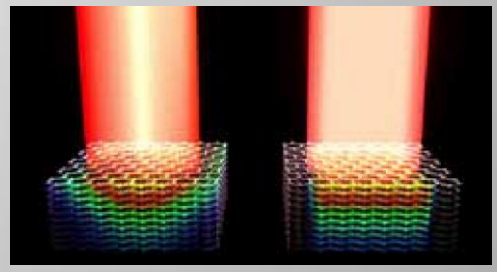
- Introduction
- Progress & status
- Next steps

*See also IWXM 2015 Tuesday 4:30 PM, "**At-wavelength experiments with a 45-cm long X-ray deformable mirror at the ALS**" by Lisa Poyneer*

Adaptive X-ray Optics

- Why adaptive optics?
  - Correct mirror-polishing errors
  - On-demand beam shaping
  - Near real-time dynamic correction
- Why Lawrence Livermore?
  - LLNL visible-light AO expertise
  - LLNL X-ray optic expertise





Rendering by Kwei-Yu Chu

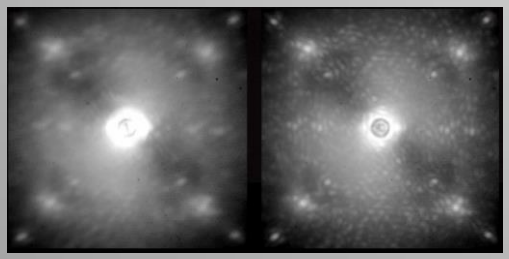
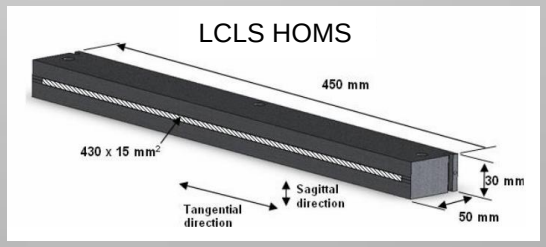


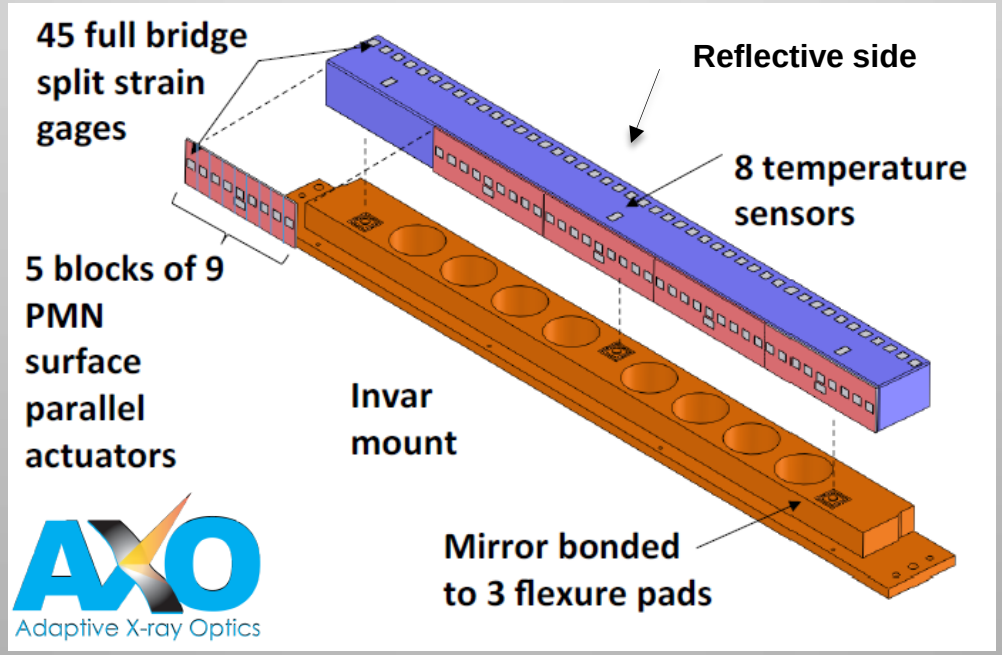
Image credits: GPI team



T. J. McCarville, et al., SPIE Vol. 7077 (2008)

Adaptive X-ray Optics @ LLNL

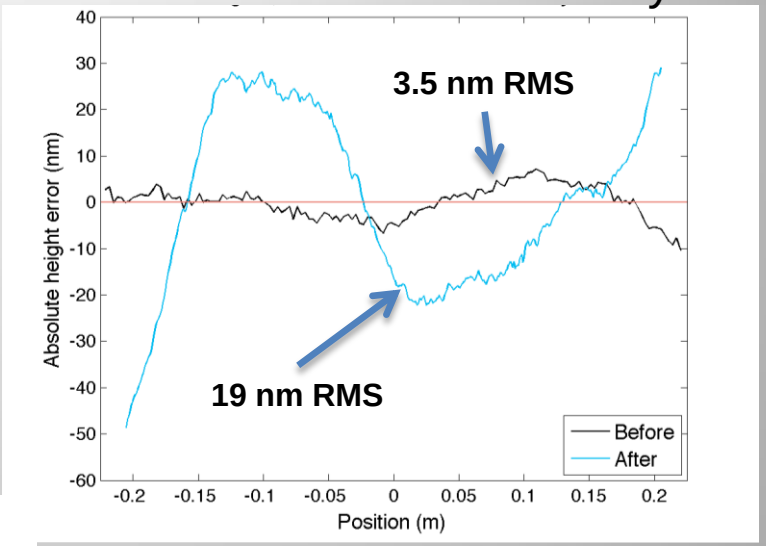
- 45x3x4 cm^3 single-crystal silicon substrate
- Developed with Northrop Grumman



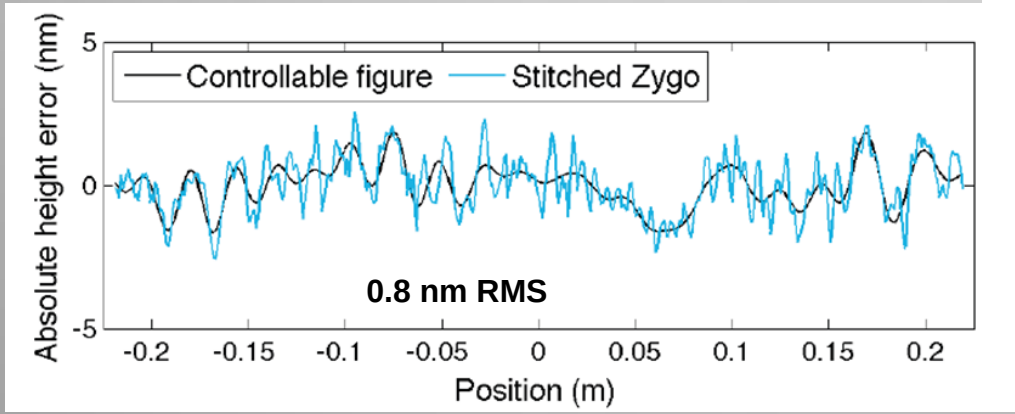
Published results

- HSFR ~0.37 nm RMS
- MSFR ~0.52 nm RMS
- LSFR (figure error)

Before and after assembly



After actuation



For additional details refer to:

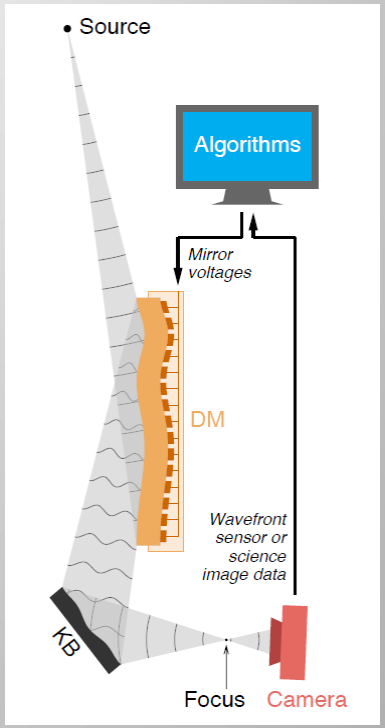
L. A. Poyneer, et. al, Applied Optics Vol. 53, No. 16, pp. 3404-3414 (2014)

&

L. A. Poyneer, et. al, Proc. SPIE 9208, 92080F (2014)

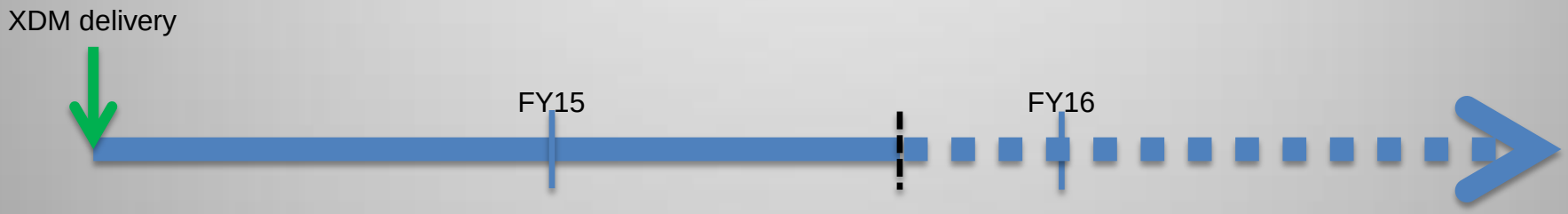
Development focus areas of project

- System-level performance
  - Deformable mirror technology
  - Metrology techniques
  - Modeling and simulations



Solid base for next-gen development in partnership with light source

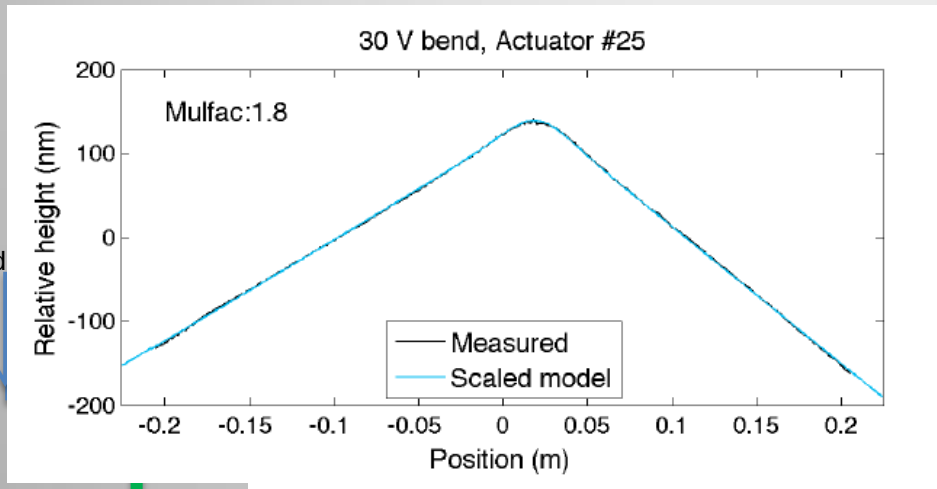
Project timeline

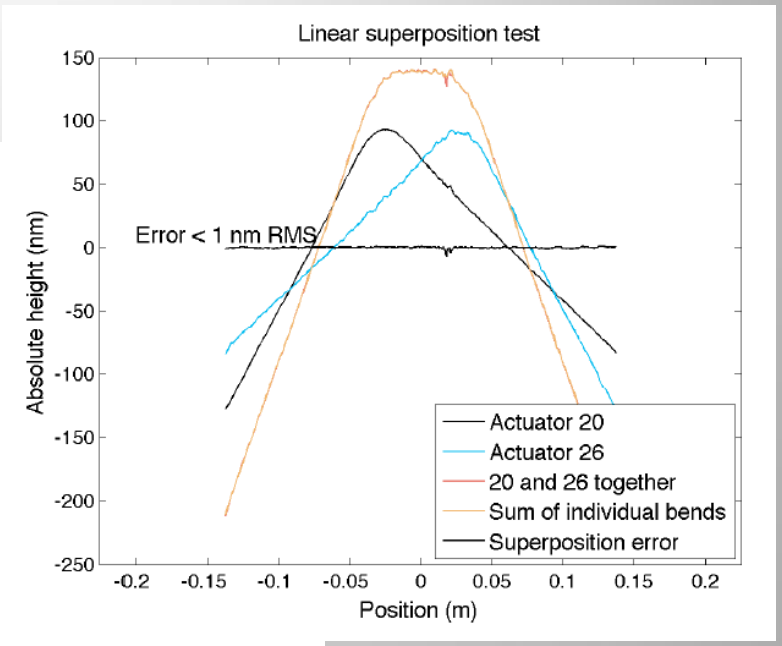


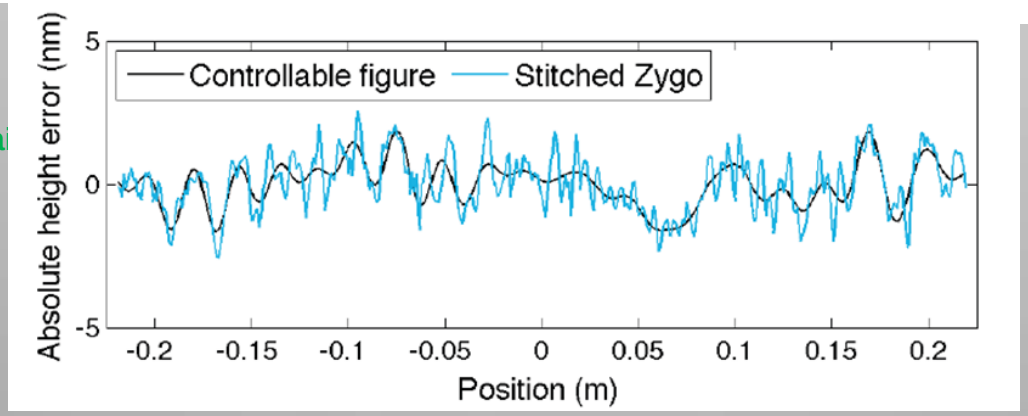
Metrology campaign

XDM d

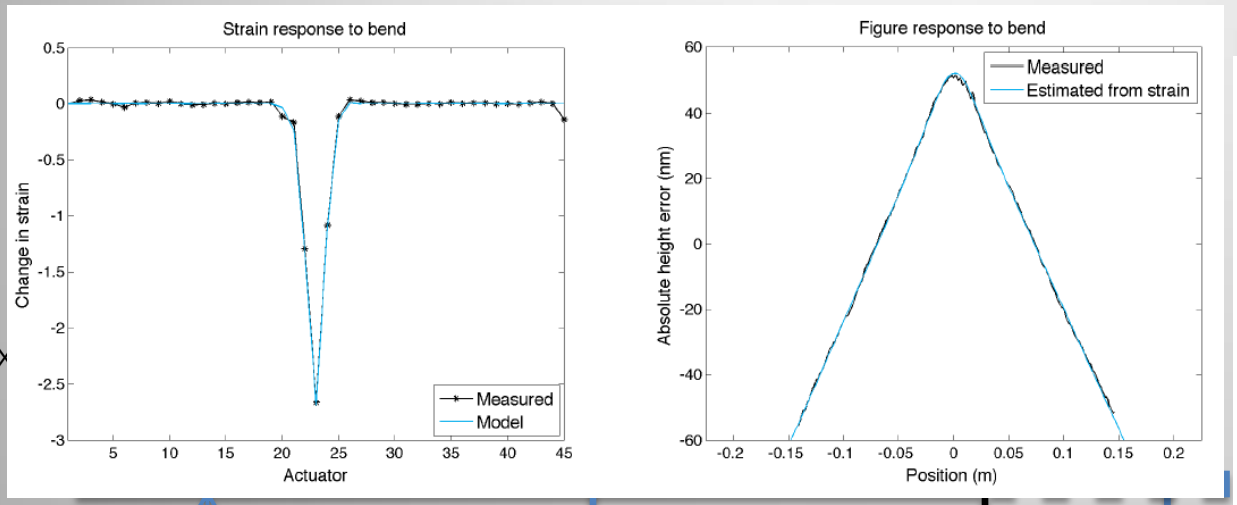
Metrology campai

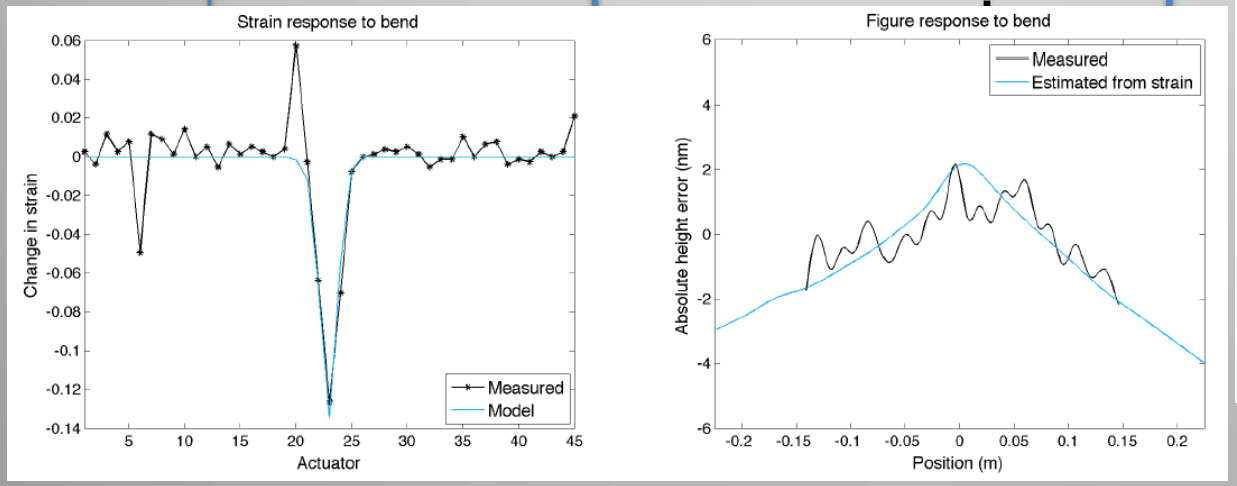


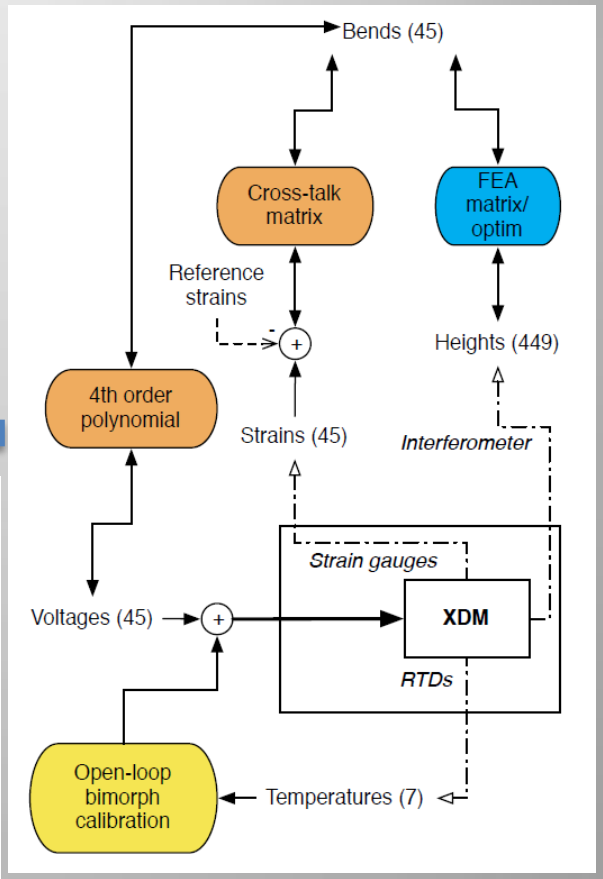




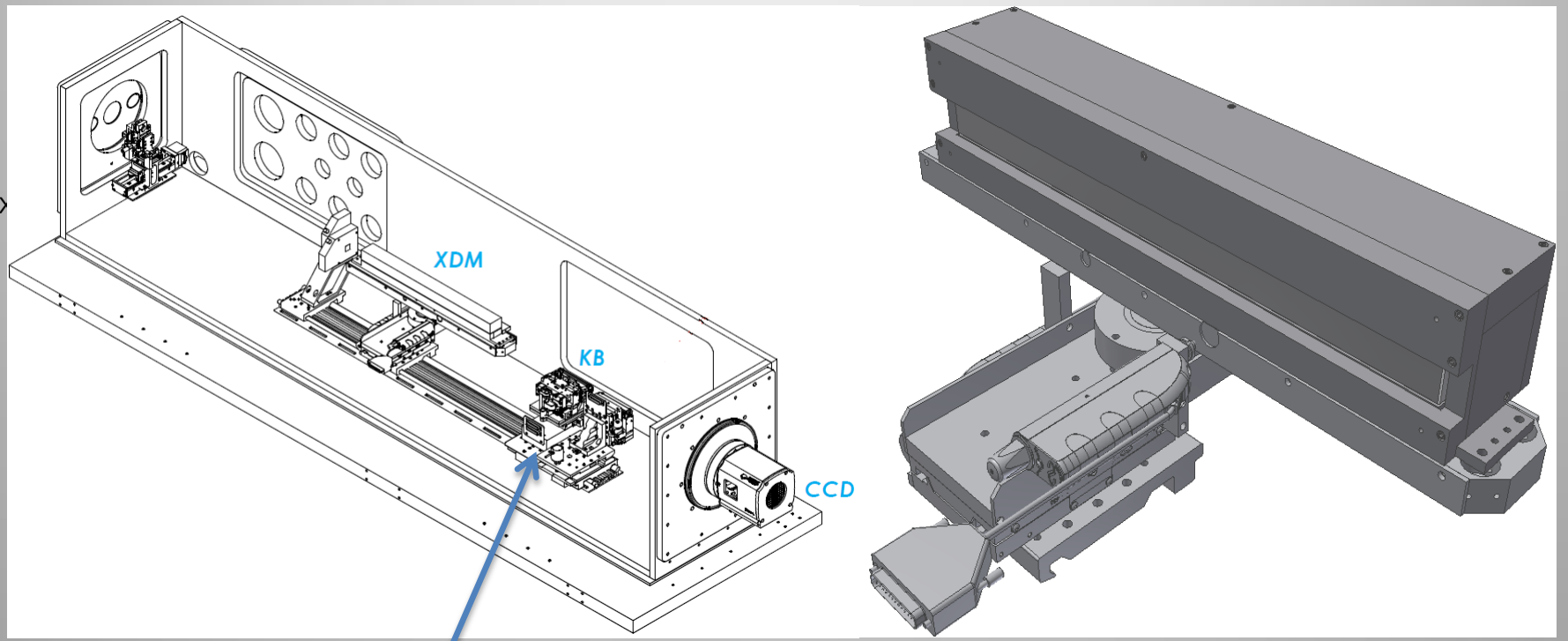
In situ metrology campaign





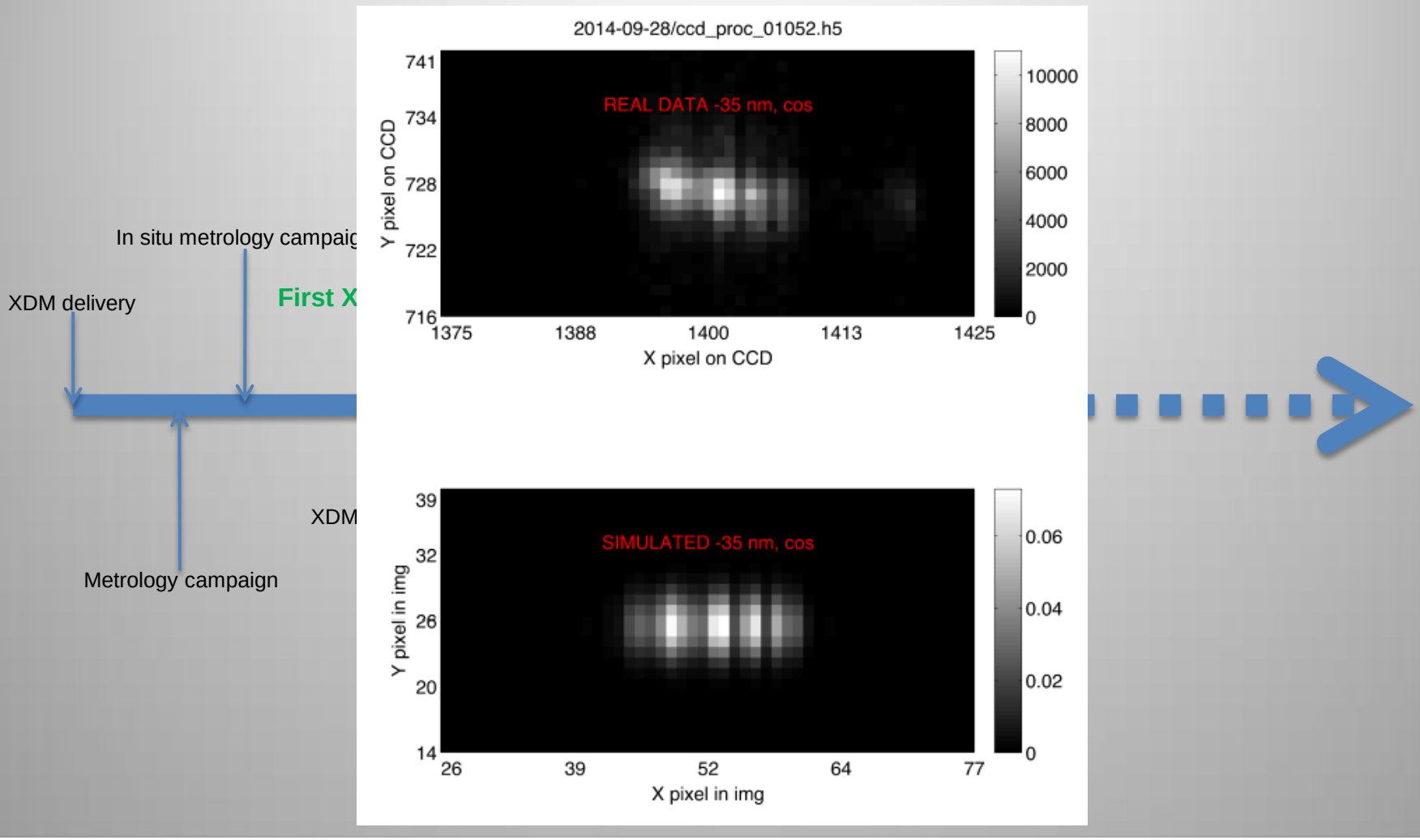


XDM install at ALS 5.3.1

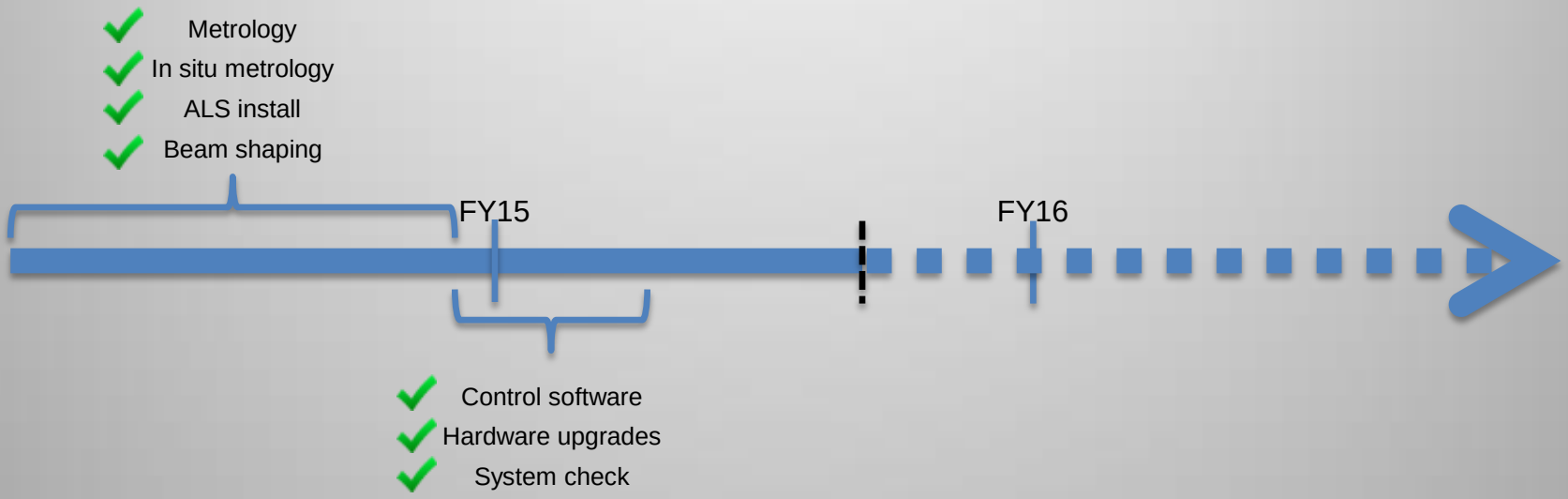


KB reference: S. Yuan, et. al, Proc. SPIE 7801, 78010D (2010)

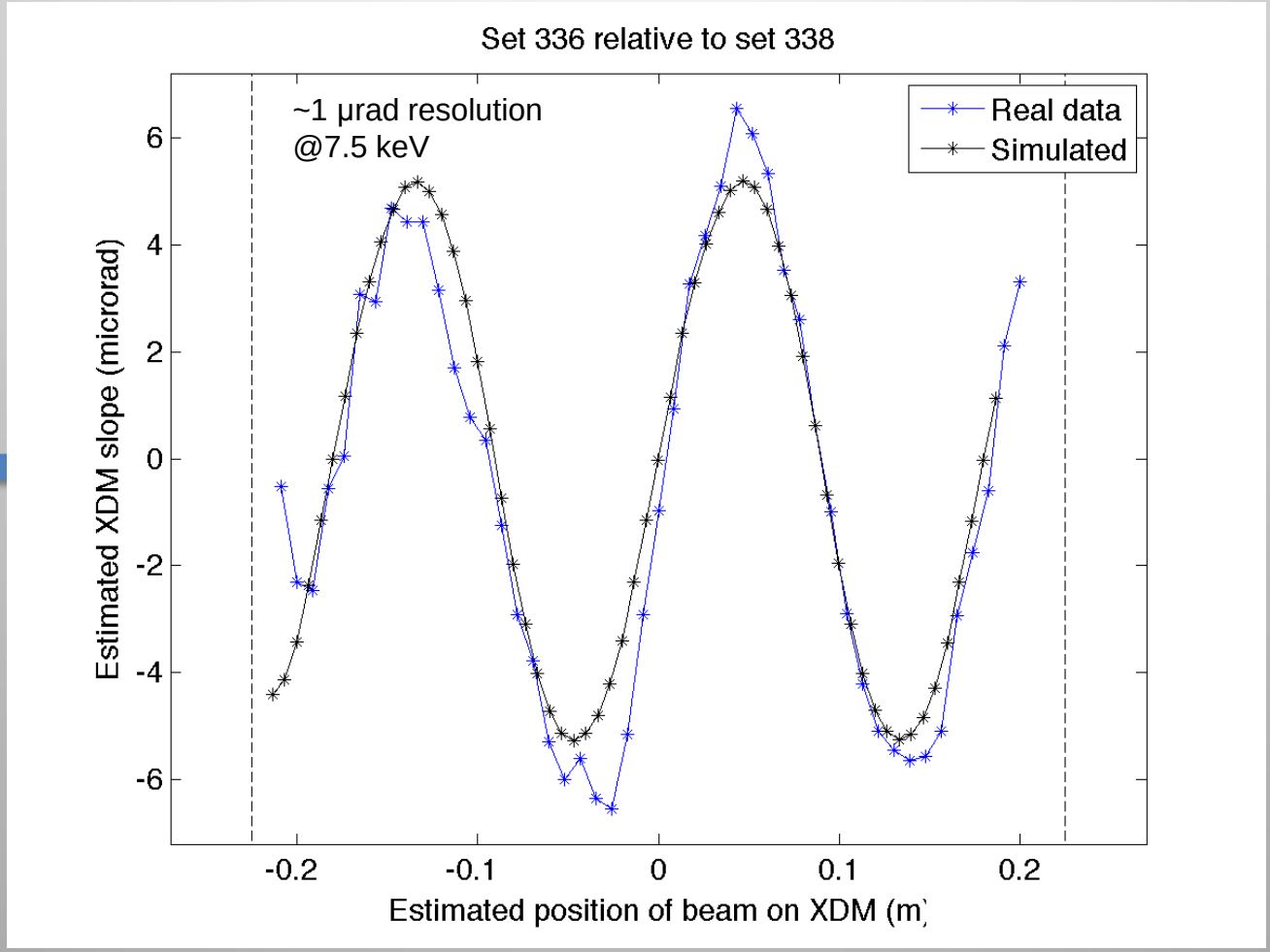
First X-ray beam shaping



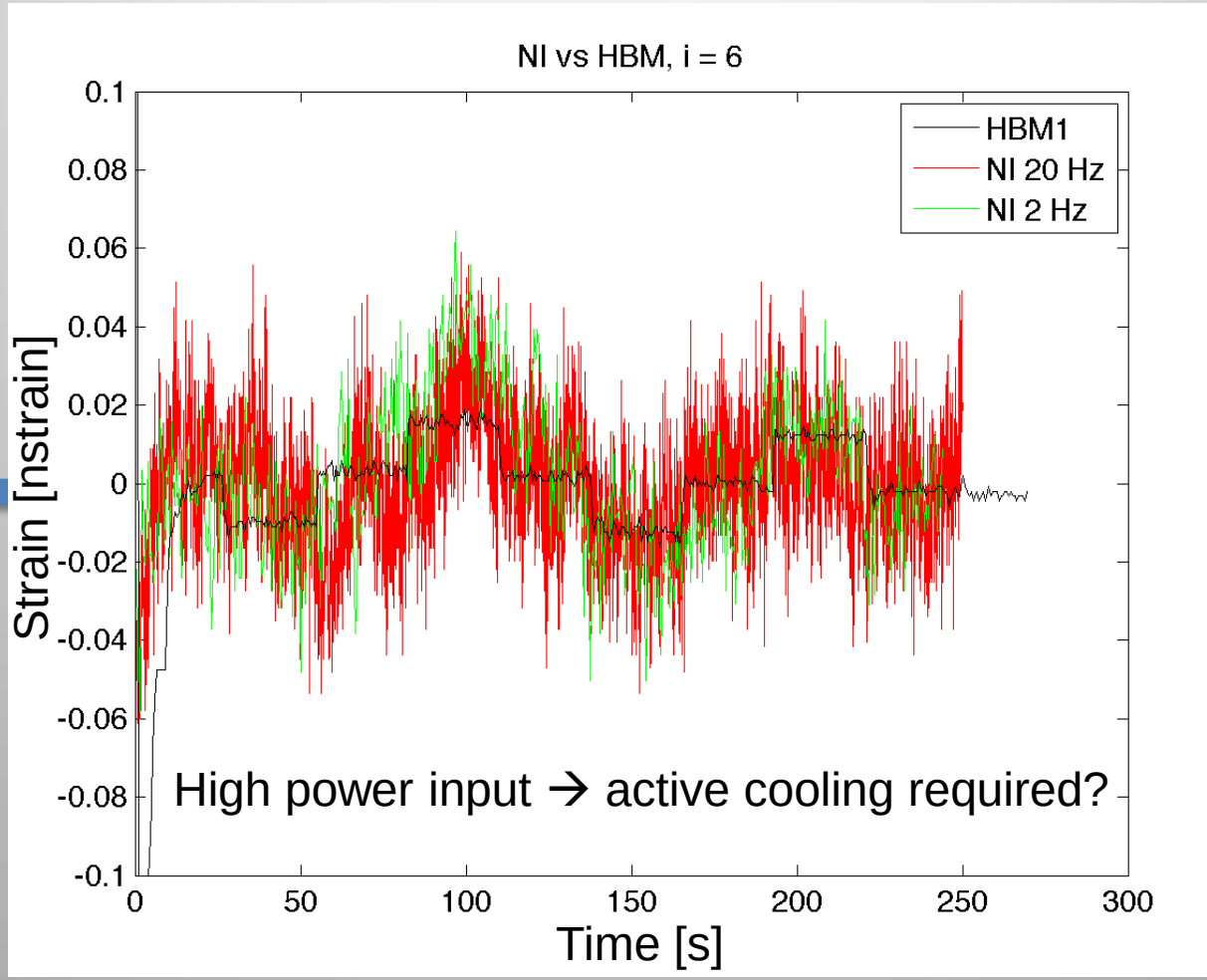
Getting settled in



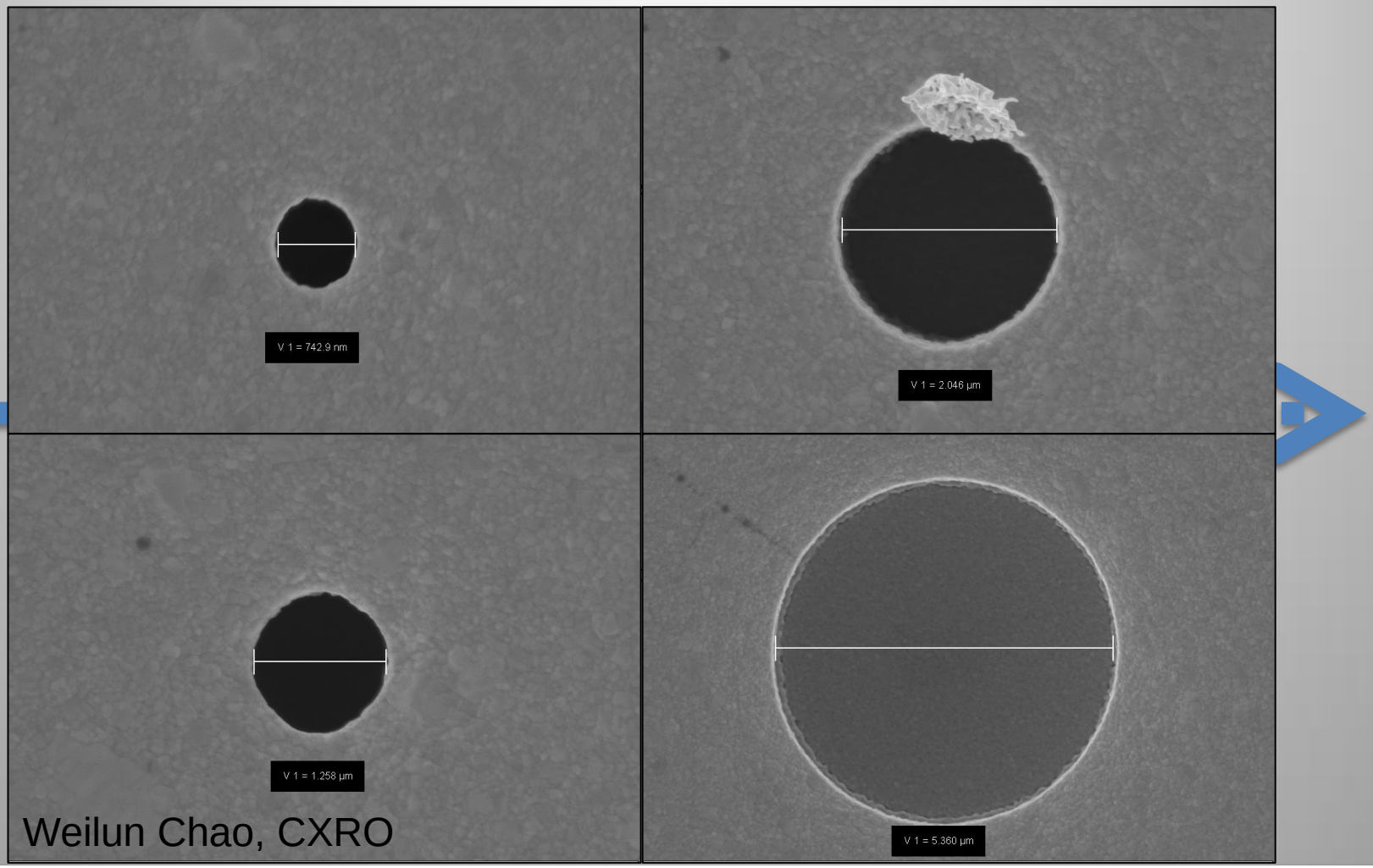
At-wavelengh coarse metrology



Read-out electronics upgrade

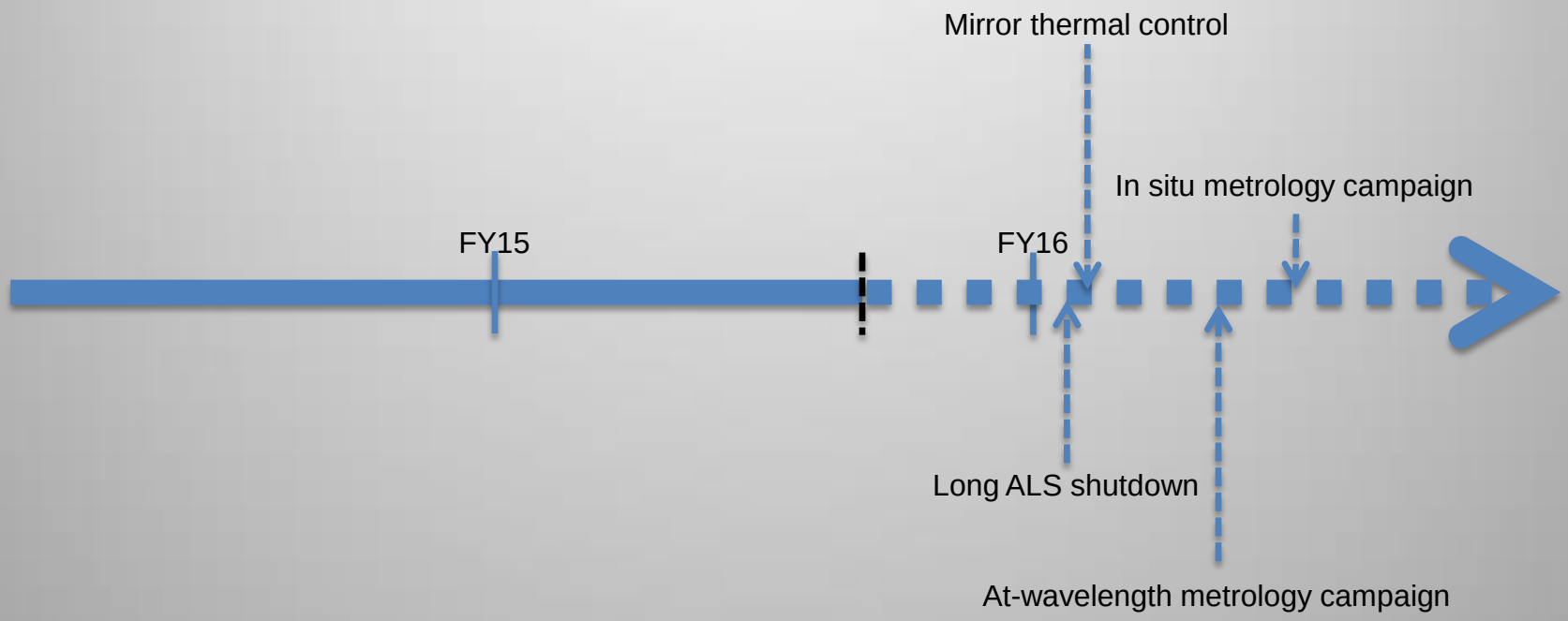


Current work – mono and pinholes



Weilun Chao, CXRO

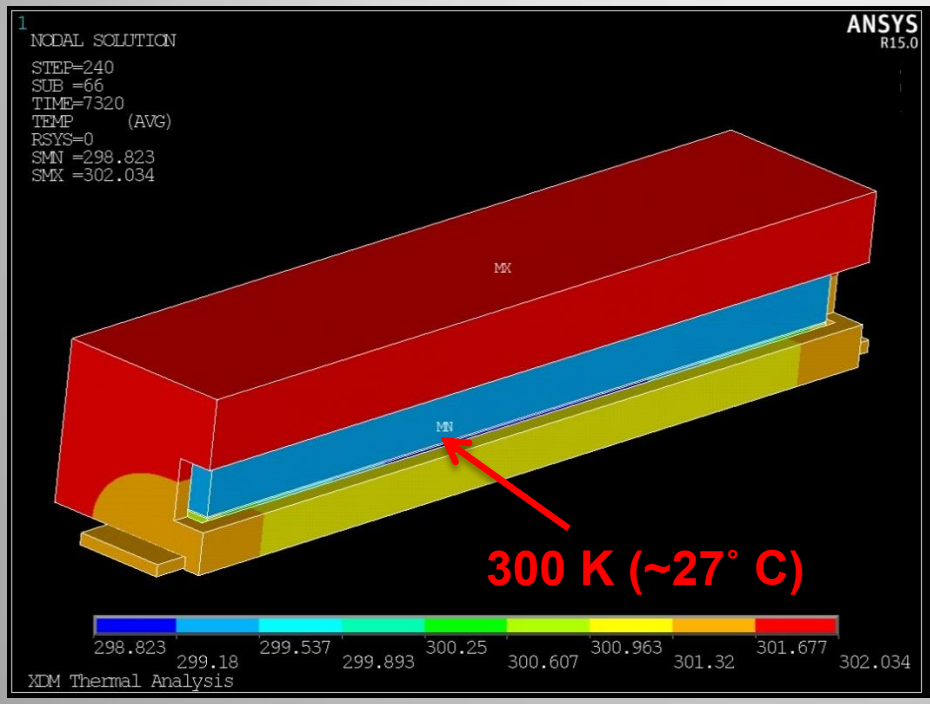
Next steps


Mirror thermal control
In situ metrology campaign
FY15
FY16
Long ALS shutdown
At-wavelength metrology campaign

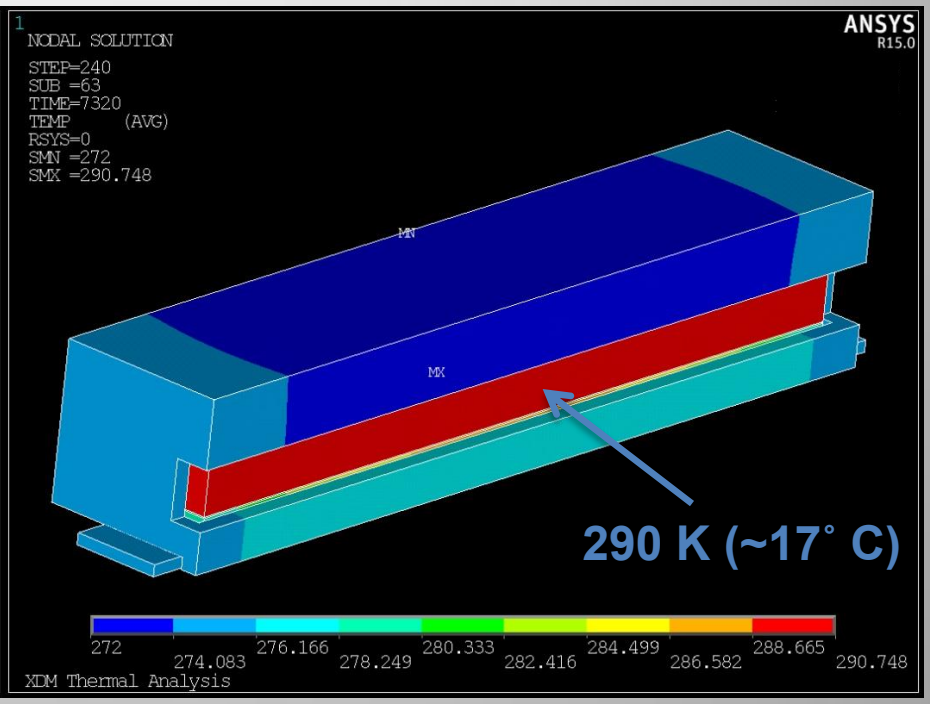
Next steps

- Qualify hardware upgrades
  - Mono, pinholes, support hardware
- Qualify new software
  - New readout electronics, simulation tools
- Finalize alignment and qualification procedures
- Finalize mirror thermal control plans
- Finalize metrology upgrade plans

Mirror thermal control



Climbing quick



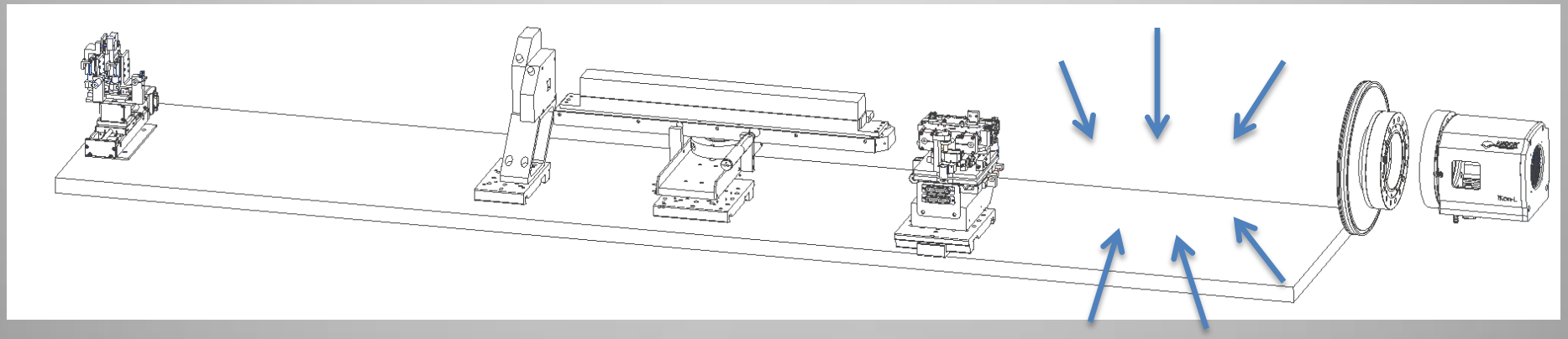
Actively cooled

Metrology status

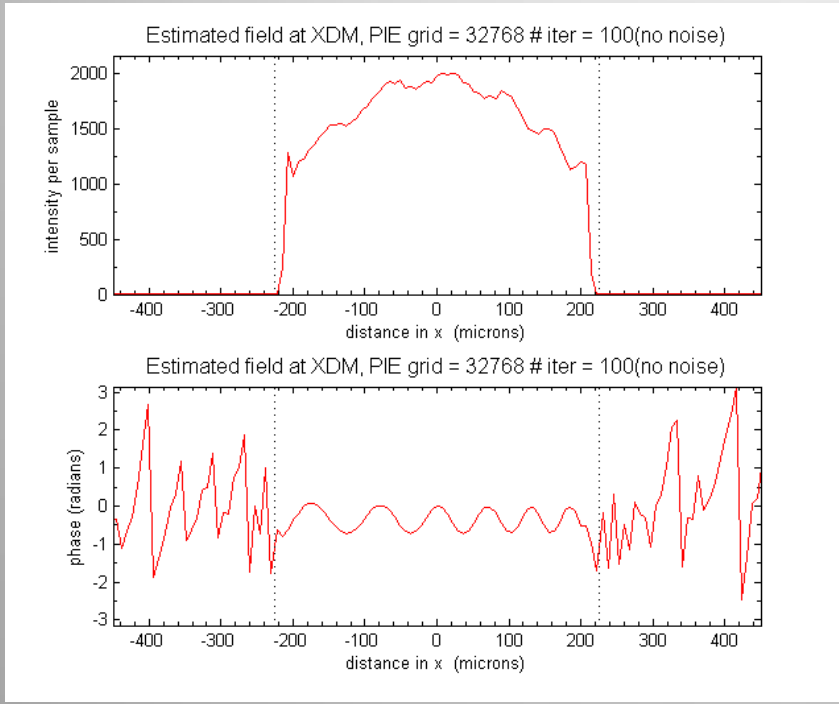
	Visible	"Coarse" at-wavelength	"Fine" at-wavelength	Strain gauges
FY14	**Closed-loop < 1 nm**	**Specify**	**Identify**	**Open-loop < 10 nm**
FY15	**-**	**Measure ~1 µrad Closed-loop < 1 µrad**	**Specify**	**Measure < 5 nm**
FY16	**-**	**-**	**Measure < 1 nm Closed-loop < 1 nm**	**Closed-loop < 1 nm**

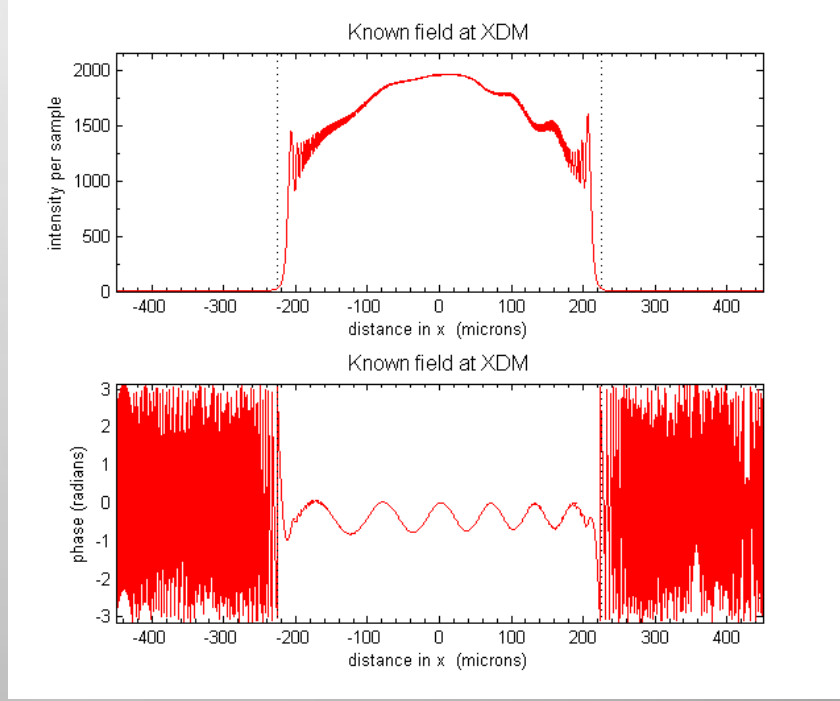
Metrology status

- Investigating well-established methods
  - Ptychography
  - Shearing interferometry (IWXM 2015)



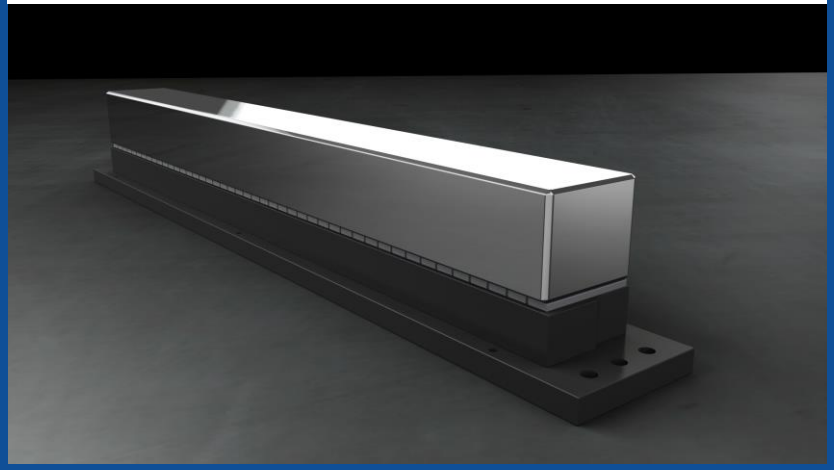
Metrology status - ptychography





AXO

Adaptive X-ray Optics @ Lawrence Livermore National Laboratory



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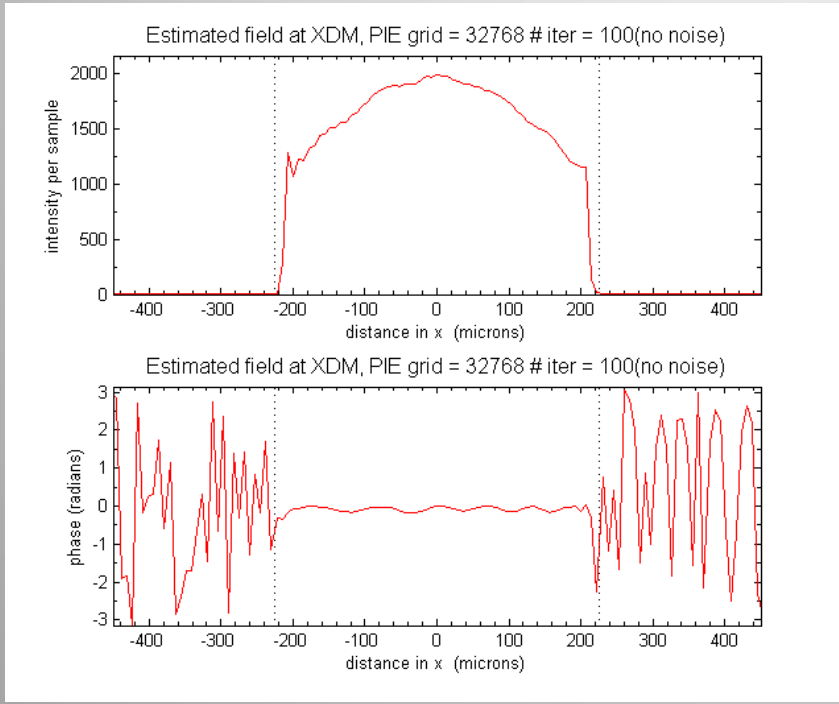
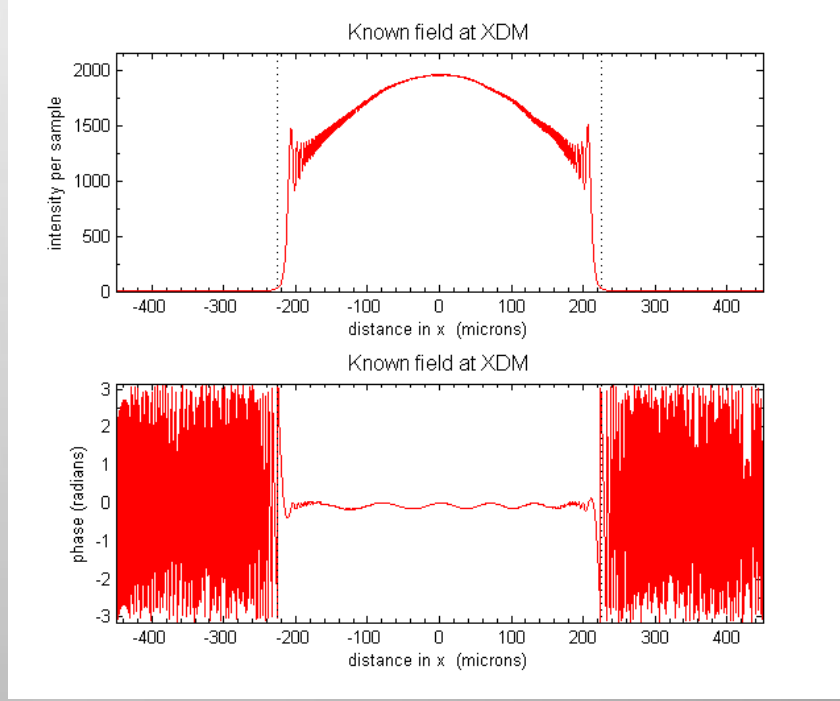
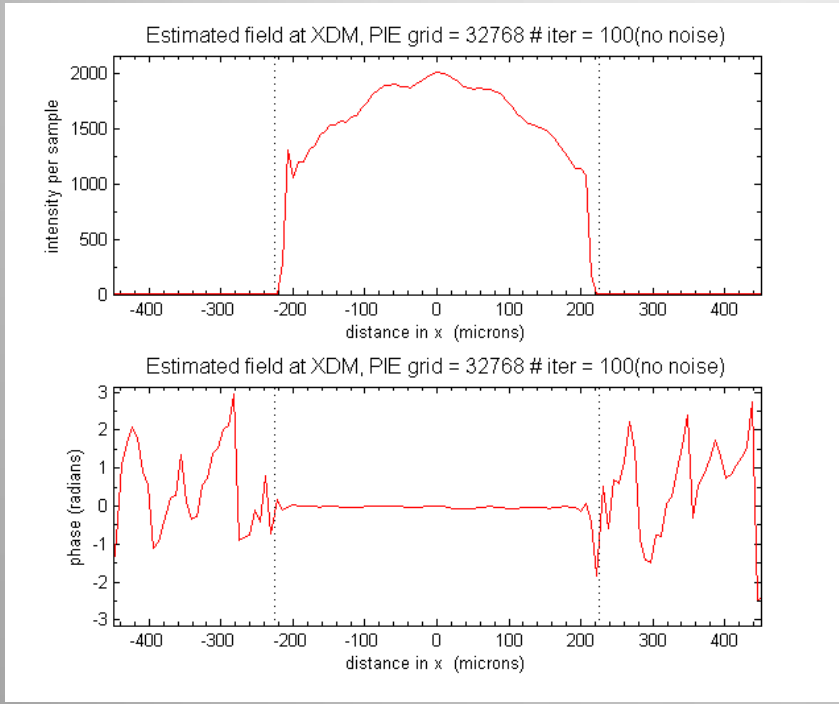
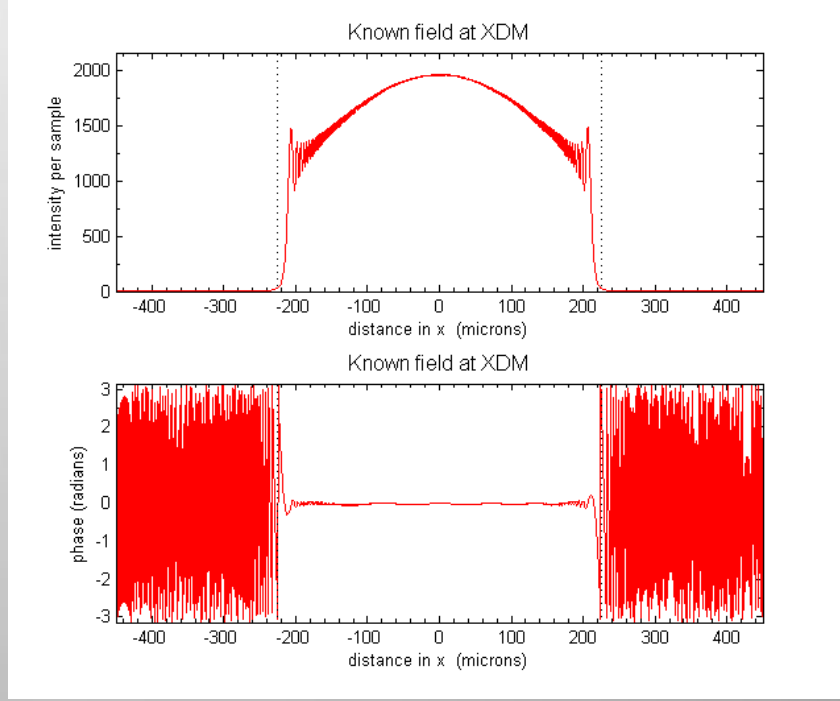
Metrology status – 3 nm ripple





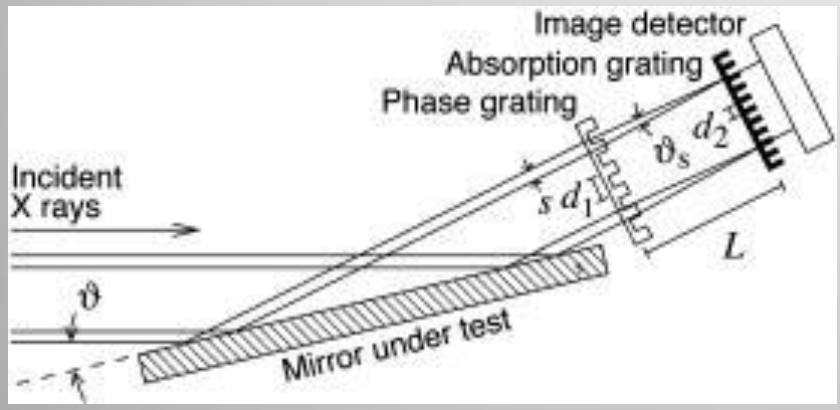
Metrology status – 1 nm ripple





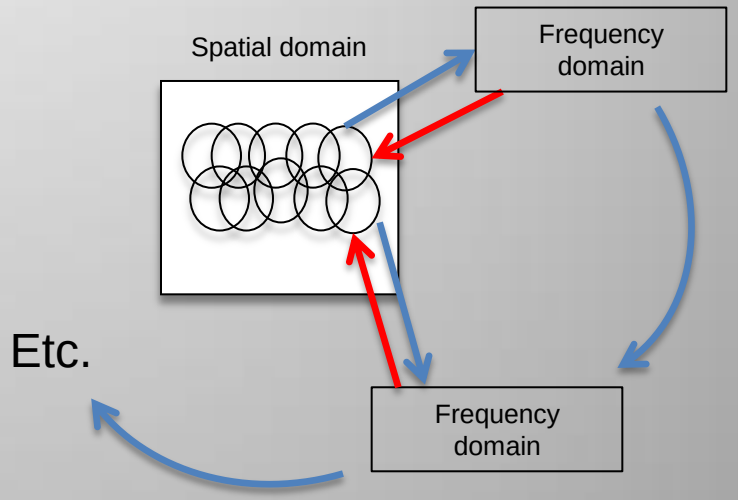
Metrology

Shearing interferometer

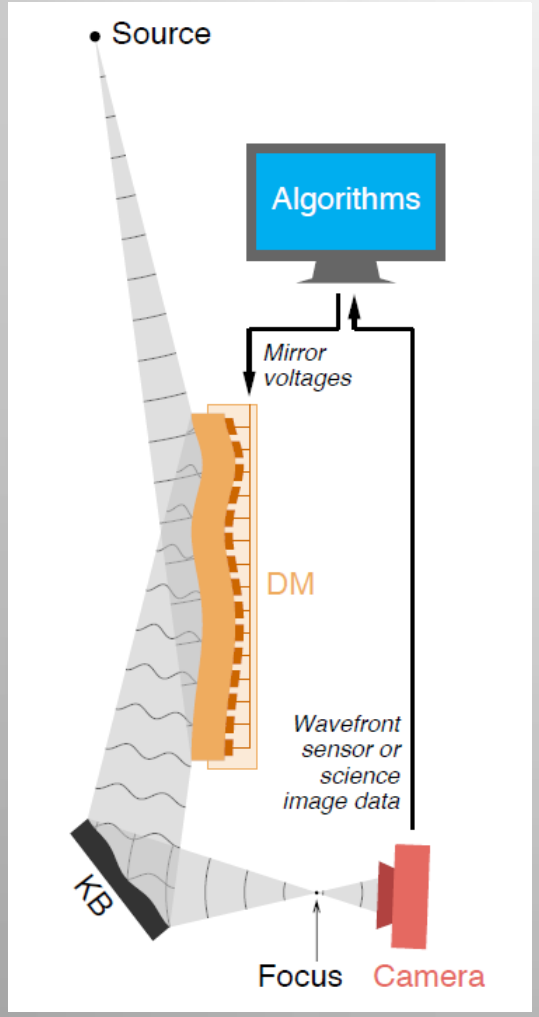


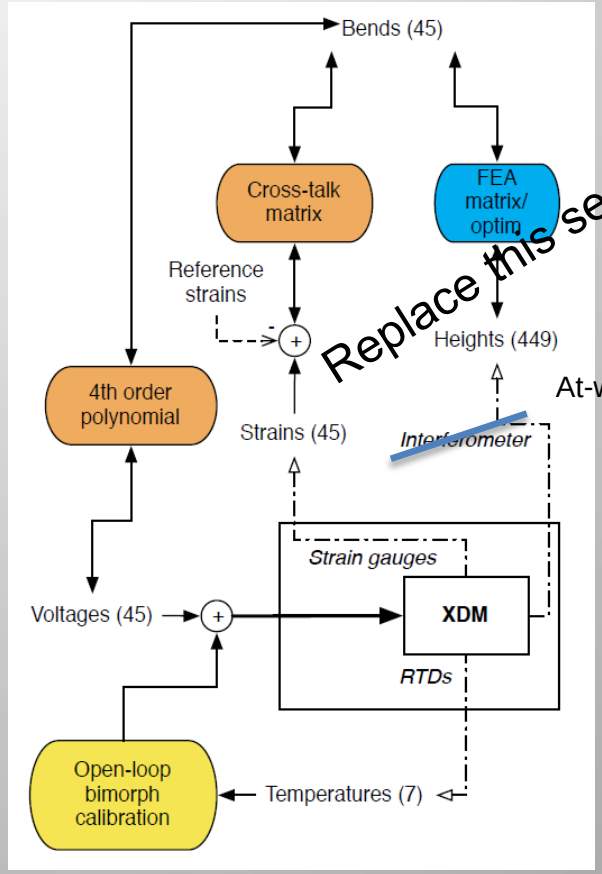
T. Weitkamp et al.,
Appl. Phys. Lett. **86**, 054101 (2005)

Ptychography



Closing the loop, at-wavelength





Replace this segment with

At-wavelength sensor